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N-1130 - Rpt #9(Final)
Contract: DA19-129-qm-1307
Vanderbilt University

Protective Effects of Certain Natural
Foods Against Whole-Body Irradiation

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Period: 14 October 1958 - 31 January 1961

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QUARtermaster FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES
Research and Engineering Command
Quartermaster Corps, U.S. Army
Chicago, Illinois

N-1130 - Rpt #2(Final)
Contract: DA19-129-qm-1307
Vanderbilt University

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Foods Against Whole-Body Irradiation

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QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES
Research and Engineering Command
Quartermaster Corps, U.S. Army
Chicago, Illinois

CONTRACT RESEARCH PROJECT REPORT

QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES, CHICAGO
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Project Nr.: 7-84-13-002A
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Report Nr. 9(Final)
File Nr: N-1130
Period: 14 October 1958 -
31 January 1961
Initiation Date: 14 Oct 1958

Title of Contract: Protective Effects of Certain Natural
Foods Against Whole-Body Irradiation

ABSTRACT

Period: 15 October 1960 to 31 January 1961

Eighteen Rhesus monkeys were maintained on an adequate, purified diet for a year and then divided into two groups: (1) Four males and four females were continued on the purified diet; (2) Five males and five females were fed Purina Monkey chow plus some natural foods (Swiss chard, carrots, apples and bananas) instead of the purified diet. After eight weeks all animals were given 700 r total-body x-irradiation. Combined data for males and females show that out of eight animals on the purified diet, only two survived longer than 35 days post-irradiationally. Out of ten animals fed the monkey chow plus natural foods, six survived longer than 35 days. Slight weight loss was experienced after irradiation, and those animals surviving 35 days showed the smallest weight loss. Weight loss was paralleled by decrease in food intake post-irradiationally. The two groups had similar hematological responses to the irradiation (i.e., decreased leucocyte counts, decreased hematocrits, and decreased hemoglobin concentration).

Period: 14 October 1958 to 31 January 1961

Experiments with Sprague-Dawley Rats:

Rats maintained on a purified diet were divided into groups: A control group maintained on purified diet alone; other groups in which the basal diet was supplemented with either broccoli, green beans, or mustard greens.

Animals were given either 800 r or 700 r (different experiments) total-body x-irradiation. Male rats fed broccoli or mustard greens

and given 800 r total-body x-irradiation had a slightly longer survival time than animals given basal diet alone. However, in an experiment in which male rats were given 700 r total-body x-irradiation, animals on basal diet alone survived as long as those receiving natural food supplements.

Female rats fed mustard greens and given 800 r total-body x-irradiation showed better survival than either controls fed basal diet alone or those given broccoli supplements. However, when the irradiation dose was decreased to 700 r no significant differences were observed between the three groups.

Experiments with Guinea Pigs:

Difficulty was encountered in maintaining guinea pigs on a diet of local bran and oats (plus ascorbic acid). If this diet was supplemented with either broccoli or mustard greens, mortality decreased sharply (prior to irradiation) so that in two weeks no animals (out of 33) on either of these supplements died, but a mortality of 25 out of 33 was observed in the group maintained only on local bran and oats. A diet similar to that described by Reid and Briggs was readily accepted by the guinea pigs. No mortalities occurred on this diet prior to irradiation. Animals given broccoli plus this diet and irradiated with 400 r total-body x-irradiation showed no better survival than controls on the basal diet alone. Pigs given mustard greens as supplement had slightly better survival than controls (9 out of 20 compared to 4 out of 20).

Bran and oats supplied by the Quartermaster Food and Container Institute in Chicago proved to be more effective than local bran and oats but not as effective as the diet of Reid and Briggs in

maintaining guinea pigs prior to irradiation. A mineral supplement added to bran and oats supplied by the Quartermaster Food and Container Institute improved the diet to some extent.

Experiments with Monkeys:

Supplements of broccoli or mustard greens to monkeys fed a purified diet did not improve survival (compared to controls fed purified diet alone) after 700 r total-body x-irradiation.

Experiments with monkeys fed selected natural foods have been already described.

those fed purified diet (see Table 1). Combined figures for males and females show that out of eight animals on the purified diet, only two survived longer than 35 days postirradiationally. Out of ten animals fed the natural food diet, six survived longer than 35 days.

(b) Weight loss was slight or insignificant in most of the animals (Table 2). Slight weight loss occurred in general during the period immediately following irradiation. Those animals surviving 35 days showed the smallest weight loss.

(c) An attempt was made to estimate food consumption pre- and post-irradiationally. Prior to irradiation all monkeys consumed most or all of the food given to them except for the horse meat offered the animals in Group 2. No significant amount of this food was consumed by any animal. Post-irradiationally, the monkeys in Group 1 decreased their intake during the first few days to a low of 20% of normal at the end of two weeks. A significant decrease in food intake occurred in animals on natural foods at the end of the first week and was down to about 40% of normal at the end of two weeks. Increased food consumption was observed in both groups by the end of the third week with near normal intakes being established by 35 days in all groups except females of Group 1. Intake of the survivors of this group remained at about 50% of pre-irradiational levels.

(d) Hematological studies showed that the groups responded to the irradiation in similar fashion.

Leucocyte count (Table 3) decreased in all groups after irradiation, with the lowest values observed at 14 days. Recovery had occurred by the 28th day in those animals which survived.

It is interesting that just prior to irradiation (-1 day) the animals fed the natural foods had lower leucocyte counts than did those on the purified diet.

Hematocrit values (Table 4) decreased sharply in all groups about two weeks after irradiation. Recovery in those surviving had begun by the 28th day but values were not yet normal by the 35th day. Monkeys receiving natural foods had slightly higher hematocrit values at 14 days post-irradiation than did those receiving purified diet. There were no differences apparent before irradiation (-1 day).

The results of determinations of hemoglobin concentration (Table 5) paralleled closely the hematocrit data.

Summary of Period: 14 October 1958 to 31 January 1961

Experiments with Sprague-Dawley Male Rats

1. Rats were maintained on purified basal diet and then divided into 3 groups of 25 each: controls fed basal diet; basal diet plus broccoli; basal diet plus green beans. After two weeks on the test diets the animals were given 800 r total-body x-irradiation. All controls were dead by the thirteenth post-irradiational day. Animals fed broccoli all died by the eighteenth day. Two animals fed mustard greens survived past 21 days. Better growth was observed in the animals fed the vegetables. Hemoglobin concentration and hematocrits decreased more slowly post-irradiationally in these animals than in the controls (basal diet alone).

2. After a 14-day period on test diets rats were given 700 r

total-body x-irradiation. The following 21-day survivals were noted:

<u>Test Diet</u>	<u>Number irradiated</u>	<u>Number Surviving 21 Days</u>
Basal diet	20	13
Basal diet plus broccoli	20	11
Basal diet plus mustard greens	20	8
Basal diet plus green beans	10	5

No differences between groups were noted in studies of food consumption, growth, or hematology.

Experiments with Sprague-Dawley Female Rats

1. Female rats were maintained for two weeks on a purified diet and then divided into 3 groups of 20 each: one group fed basal diet alone; one group fed basal diet plus broccoli; and one group fed basal diet plus mustard greens. After two weeks on the test diets all animals were given 800 r total-body x-irradiation. Twenty-one day survivors were the following: 4 controls, 3 fed broccoli and 12 fed mustard greens. A decrease in body weight and in food consumption occurred in all groups after irradiation. No differences in hematological values were noted between the groups.

2. After a 14-day period on test diets three groups (20 per group) of female rats were given 700 r total-body x-irradiation. The following survived 21 days:

<u>Test Diet</u>	<u>Number Surviving 21 days</u>
Basal diet alone	1
Basal diet plus broccoli	2
Basal diet plus mustard greens	3

No differences in body weights, food consumption, or hematological values were noted between the groups.

Experiments with Male Guinea Pigs

1 Male Aristocratic guinea pigs were maintained on bran and oats (plus ascorbic acid) for two weeks. They were then divided into 3 groups of 16 each and maintained for 14 days on basal diet of bran and oats alone, basal diet plus broccoli, or basal diet plus mustard greens.

Only 5 animals fed basal diet alone survived the pre-irradiation period. One animal fed broccoli and no animals fed mustard greens in addition to the bran and oats died during this time. The survivors were given 400 r total-body x-irradiation. All 5 controls died by the 6th day after irradiation. At 21 days postirradiationally 4 animals fed broccoli and 3 animals fed mustard greens survived.

The control group lost weight during the preirradiational period while the other two groups showed weight loss only post-irradiationally. Irradiation caused only a slight decrease in food consumption.

Experiments with Female Guinea Pigs

1. After a two-week period on bran and oats (plus ascorbic acid) Rockland female guinea pigs were divided into 3 groups and placed on various test diets. The following results were noted after two weeks:

<u>Test Diet</u>	<u>Number on Diet</u>	<u>Number Surviving Two Weeks</u>
Bran & Oats alone(plus vitamin C)	33	8
Bran & Oats plus broccoli	33	33
Bran & Oats plus mustard greens	33	33

The surviving controls were given a known vitamin mixture plus the basal diet. Only three animals survived a two-week period on this regime. This experiment was terminated at this point.

2. Rockland female guinea pigs were maintained for two weeks on a diet similar to that described by Reid and Briggs. They were then divided into 3 groups of 20 each and broccoli or mustard green supplementation started for two of these groups. No mortalities were noted during the two-week test period. The animals were given 400 r total-body x-irradiation and the following 40-day survivors noted:

<u>Test Diet</u>	<u>Number Surviving forty days</u>
Basal diet alone	4
Basal diet plus broccoli	4
Basal diet plus mustard greens	9

Those animals on mustard greens showed the smallest decrease in body weight, while those on broccoli had the largest decrease in body weight.

Food consumption in all groups decreased sharply during the second week postirradiationally.

3. Rockland female guinea pigs, maintained for two weeks on a diet similar to that described by Reid and Briggs, were divided into 2 groups of 20 each. One group was fed bran and oats from a local supplier (plus ascorbic acid); the other group was fed bran and oats supplied by the Quartermaster Food and Container Institute (plus ascorbic acid). After 6-1/2 weeks there were 10 survivors in the first group and 15 in the second. Animals in the first group lost more weight and had lower hematocrits and hemoglobin concentrations than those in the second group.

The survivors were given 400 r total-body x-irradiation. All ten animals from the first group were dead by the 15th day; all fifteen animals of the second group were dead by the 17th day. There was loss of weight and food consumption in both groups after irradiation.

4. Rockland Farm female guinea pigs were maintained on guinea pig chow for three weeks and then divided into 4 groups.

- A - fed bran and oats from local supplier (plus ascorbic acid)
- B - fed bran and oats from local supplier (plus ascorbic acid) plus a mineral supplement equivalent to that of Reid and Briggs' diet.
- C - bran and oats from Quartermaster Food and Container Institute (plus ascorbic acid)
- D - bran and oats from Quartermaster Food and Container Institute (plus ascorbic acid) plus the mineral supplement noted in B.

After a one-month period on these diets the following survivors were noted:

<u>Group</u>	<u>Number of Survivors</u>
A	1
B	4
C	4
D	8

All survivors were given 400 r total-body x-irradiation. There were no survivors past 6 days postirradiationally.

Experiments with Monkeys

1. Rhesus monkeys were kept on a purified diet for several weeks and then placed on test diets according to the following schedule:

<u>Diet</u>	<u>No. of Males</u>	<u>No. of Females</u>
Basal diet alone	2	2
Basal diet plus broccoli	3	3
Basal diet plus mustard greens	3	3

After 4 weeks on these test diets the monkeys were given 700 r total-body x-irradiation. Surviving 30 days were 2 males fed mustard greens, 1 male control, and 1 female control. Following irradiation, decreased food consumption and body weight were noted in all animals. No differences among the groups were noted in hematological values.

2. Monkeys Fed Purified Diet or Purina Monkey Chow Plus Certain Natural Foods.

This experiment is detailed in the initial portion of this report.

Out of ten animals fed the natural foods plus monkey chow, 6 survived at least 35 days after 700 r total-body x-irradiation.

Out of eight animals fed purified diet, only two survived longer than 35 days following 700 r total-body x-irradiation.

TABLE 1
Survival Rate for Monkeys Given 700 r Total-Body
Irradiation

<u>Experimental Group</u>	<u>Number of Monkeys</u>	<u>Number of Days Survived Postirradiationally</u>
Males Fed Purified Diet	1 1 1 1	16 17 18 25
Males Fed Natural Foods	1 4	18 >35
Females Fed Purified Diet	1 1 1 1	16 17 18 >35
Females Fed Natural Foods	1 1 1 2	14 16 18 >35

TABLE 2

Body Weights* of Monkeys Before and After
Total-Body Irradiation

<u>Experimental Group</u>	<u>Monkey No.</u>	<u>Days Before Irradiation</u>		<u>Days After Irradiation</u>			<u>Day of Death</u>
		<u>-28</u>	<u>-1</u>	<u>+7</u>	<u>+14</u>	<u>+35</u>	
Males Fed Purified Diet	275	3.6	4.0	3.3	3.4		3.3
	272	3.5	3.3	3.6	3.5		3.3
	267	3.8	3.8	3.6	3.6	3.8	
	271	3.4	3.6	3.4	3.0		2.9
Males Fed Natural Foods	268	3.2	3.5	3.4	3.4	3.4	
	269	3.6	3.9	3.7	3.6	3.7	
	270	3.6	3.8	3.8	3.8	3.7	
	276	3.1	3.3	3.2	2.9		2.7
	274	3.3	3.5	3.3	3.6	3.5	
Females Fed Purified Diets	262	2.5	2.5	2.4	2.5		2.4
	259	2.8	2.7	2.6	2.6		2.6
	264	3.7	3.8	3.5	3.6	3.7	
	265	4.7	4.6	4.6	4.3		4.2
Females Fed Natural Foods	256	4.1	4.4	4.2	4.2	4.2	
	257	3.2	3.4	3.2	3.2	3.0	
	261	2.9	2.9	2.7	2.7		2.8
	263	3.7	4.0	3.9	3.7		3.8
	266	3.1	3.4	3.0	3.2		3.2

* kilograms

TABLE 3

Leukocyte Count* of Monkeys Pre- and Post-Total-Body Irradiation

Experimental Group	Monkey No.	Days Pre- Irradiation		Days Post- Irradiation				
		-28	-14	-1	+1	+7	+14	+21 +28 +35
Males Fed Purified Diet	275	11000	21200	19000	16800	800	950**	
	272	9700	14600	11100	9800	1000	1300**	
	267	12200	20200	14800	16600	1200	1450	19000 17500
	271	12700	13800	14700	11700	1400	1000**	
Males Fed Natural Foods	268	11200	14000	12100	8600	1100	1000	8900 10600 21600
	269	6900	6800	8400	10100	1800	1400	3500 9300 15900
	270	11500	14800	9600	11500	950	1350	6450 7800 24500
	276	12100	11600	13200	11700	900	1250**	
	274	14300	8900	7000	7400	1500	850	2000 5800 10400
Females Fed Purified Diet	262	12100	17500	20500	11100	1600	1700**	
	259	12500	17700	14200	7900	1750	1600**	
	264	9800	10900	16500	17300	1000	900	2700 5500 7400
	265	13900	18200	13800	11250	500	1200**	
Females Fed Natural Foods	256	7900	8100	9800	7400	1000	650	5300 8450 9600
	257	16900	13800	12400	7900	1500	550	4750 12600 29000
	261	11300	11000	6600	6750	900	700**	
	263	10100	9800	8550	12600	1000	800**	
	266	9400	8000	9500	11900	1200**		

* Per cubic millimeter

** Last Data Obtained Before Death

TABLE 4

Hematocrit of Monkeys Pre- and Post-Total-Body Irradiation

Experimental Group	Monkey No.	Days Pre-Irradiation		Days Post-Irradiation					
		-28	-14	-1	+1	+7	+14	+21	+28
Males Fed Purified Diet	275	44	46	44	44	44	27*		
	272	38	42	42	42	42	29*		
	267	39	43	42	47	43	14	14	28
	271	39	40	45	40	43	31*		32
Males Fed Natural Foods	268	45	44	45	45	44	39	27	30
	269	45	44	45	41	41	34	33	33
	270	41	40	39	40	41	34	25	32
	276	43	45	41	45	41	30*		
	274	45	44	42	44	42	33	24	30
Females Fed Purified Diets	262	39	39	40	41	39	28*		
	259	40	45	45	43	42	33*		
	264	41	39	30	30	28	28	22	22
	265	38	39	38	38	36	19*		29
Females Fed Natural Foods	256	44	43	45	42	38	33	21	35
	257	41	39	41	41	40	33	23	25
	261	42	42	42	43	40	23*		
	263	41	40	41	41	43	32*		
	266	44	39	43	42	35*			

* Last Data Obtained Before Death.

TABLE 5

Hemoglobin Concentration* of Monkeys Pre- and Post-Total-Body Irradiation

Experimental Group	Monkey No.	Days Pre-Irradiation		Days Post-Irradiation					
		-28	-14	-1	+1	+7	+14	+21	+28
Males Fed Purified Diet	275	14.2	14.2	14.2	14.5	14.2	8.9**		
	272	12.2	13.2	12.9	13.5	12.9	8.7**		
	267	13.2	13.5	13.2	14.5	13.9	4.7	4.8	9.0
	271	12.5	12.5	14.5	12.5	13.9	10.0**		11.0
Males Fed Natural Foods	268	14.5	14.0	14.2	14.8	14.2	13.2	8.7	9.6
	269	14.2	14.2	14.2	13.9	12.5	11.0	10.2	10.0
	270	12.5	12.2	12.9	12.5	12.4	10.8	7.7	10.4
	276	14.2	14.5	12.5	14.5	12.4	10.0**		
	274	14.5	14.2	13.9	14.0	14.0	11.5	8.7	9.6
Females Fed Purified Diet	262	12.9	11.9	13.2	13.2	12.2	8.9**		
	259	12.5	13.9	13.5	13.8	13.5	10.7**		
	264	12.2	11.9	9.6	9.2	9.0	9.0	7.2	7.0
	265	12.2	11.9	12.2	11.5	11.3	5.9**		9.4
Females Fed Natural Foods	256	14.2	13.9	14.2	13.5	12.9	10.8	7.0	11.3
	257	13.2	13.2	13.5	13.3	13.2	10.5	7.4	8.0
	261	13.2	13.2	13.2	13.5	12.4	8.0**		
	263	12.9	12.5	13.2	12.4	12.5	10.5**		
	266	14.2	13.2	14.2	13.5	12.9	12.9**		12.5

* Grams per 100 ml.

** Last Data Obtained Before Death

CONCLUSIONS

Although a suggestion of longer survival time was obtained in rats given mustard greens plus basal diet and irradiated with 800 r (total-body irradiation) than in rats fed basal diet alone, this was not confirmed in experiments with 700 r. Broccoli was ineffective in prolonging survival time.

A diet of local bran and oats failed to maintain guinea pigs in a nutritional state compatible with survival. Bran and oats supplied by the Quartermaster Food and Container Institute, Chicago, was more effective than local bran and oats, but a mineral supplement added to the former improved its nutritional adequacy to some extent. A diet similar to that described by Reid and Briggs proved to be the most effective in maintaining guinea pigs in a healthy state. Guinea pigs fed this diet plus broccoli survived no longer period of time after 400 r total-body x-irradiation than did animals fed the diet without any supplement. Animals given mustard greens plus the diet showed slightly longer survival time than controls.

Rhesus monkeys fed broccoli or mustard greens in addition to a purified basal diet and given 700 r total-body x-irradiation had survival times similar to animals on control diet alone.

Rhesus monkeys given Purina monkey chow plus a variety of natural foods (Swiss chard, apples, bananas, carrots) had a better survival time than animals on purified diet alone following 700 r total-body x-irradiation.

Disposition of all animals has been made in accordance with recognized humane procedures.

Funds were adequate for completion of the Contract. A complete financial statement will be sent out by the Accounting Office of the University.

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